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Enhancing Children's Success in Science Learning: An Experience of Science Teaching in Teacher Primary School Training

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Abstract
The Environmental Studies curricular area, taught at primary school level in Portugal, is a challenging context for curricular interdisciplinarity and the achievement of small-scale research and creative and innovative experiences, inside and outside the classroom. From that assumption, we present, under the master course of primary teacher training, a pedagogical intervention developed with a class of 1st and 3rd year primary school children. Our research focus was to understand to what extent the realization of experimental activities, in a class with children of different school levels, promotes the learning of science and affects other school skills. In this sense, we built and validated teaching resources whose goal is to promote science learning in the classroom, complementing this formal space with another educational context, a laboratory in a higher education institution in the same city. This study has shown that these teaching resources have provided the capacity to building interdisciplinary skills. Considering the attitudes and the affective component, it seems that this was a significant time in the children's personal and social education process, combined with active learning and socializing. We support the idea that science education in the early years of schooling is promoter of scientific literacy.
Keywords: Science teaching, primary teacher training, experimental activities, air properties

1. Introduction

Considering the diversity of strategies which can be used to promote child learning (Goldsworthy & Feasey, 1997; Naylor & Keogh, 2000; Sequeira *et al.*, 2000; Caamaño, 2002, 2003), the Environmental Studies curricular area, for its clear interrelation with the context, highlights the need for the children to approach environment-related phenomena/events according to their various learning rhythms. In this framework, science education presents interdisciplinarity and involvement potential towards the various primary school curriculum areas. In this context, practical work is a teaching resource to be considered; being essential that content teaching clearly presents the objectives and leads to learner engagement and motivation in the experimental implementation of the proposed activities. According to Hodson (1988), this didactic resource encompasses any activity in which the children are actively involved, promoting there cognitive, psychomotor and affective development.

The aim of our research was to understand to what extent the realization of practical work in Environmental Studies, in a class with children of different grade levels, promotes science learning and has an impact on other school skills. This research involved, in an active and direct way, a heterogeneous primary education group ($n = n1 + n2 = 12$) ($n1 = 8$ 1st year; $n2 = 4$ 3rd year). Bearing in mind the importance of acquiring knowledge and skills in problem-solving and communication, and of integrating the areas of natural sciences, mathematics, mother tongue and art, we have designed, implemented and validated teaching resources, articulating two educational spaces: the classroom and a laboratory in a higher education institution.

2. Theoretical Context

Science education plays a key role in shaping future active citizens, who are informed, involved, responsible and can mobilise the skills needed to interpret and monitor all scientific and technological developments in the world around them, and participate in professional life (Fumagalli, 1998; Santos, 2001, 2005; Santos & Mortimer, 2001; Tenreiro-Vieira, 2002; Lakin, 2006). Children's curiosity and creativity is crucial in their desire to discover the world that surrounds them.

Sá (2002) states that "science, a dynamically evolving structure, constitutes a privileged instrument for the stimulation of the human spirit, important to ordinary citizens, as an integral part of their intellectual development, in view of the understanding of the world in which we live and the ability to critically resolve the increasingly complex problems of today" (p. 33). According to Figueroa (2003), Woolnough and Allsop (1985), experimental activities include: exercises, experiments and research. Tenreiro-Vieira and Vieira (2006) argue that experiments can be merely illustrative and that exercises are practical. Bustamante and Aleixandre (2002) state that experiments are structured activities designed to familiarize children with certain phenomena or objects of science, which explore children's previous conceptions and promote conceptual conflicts, so as to consolidate the scientific concept.

In the Portuguese primary school curriculum we can read that " The fundamental aim is to ... develop in children an attitude of permanent experimentation with everything that that entails: observation, introduction of modifications, assessment of the effects and results, conclusions "(ME-DEB, 2004, p. 123). It is this practical work-centred education that brings out a focused perspective on educational involvement and learner autonomy. It is this perspective, of a practical nature, that leads us to promote scientific literacy. The practical work must be contextualized, valuable, with clear objectives, innovative and able to enhance autonomy and responsibility. According to Malik and Veiga (1999) "it is not conducting experiments in itself that leads to improving the success of learning, but rather the way in which these experiments are designed, the involvement of children in all stages (including the design) and its underlying intentions" (p. 4).

Experimental activities not only allow children to express their curiosity and creativity, while developing their social skills and affective reasoning, but also leads to the approach of various contents from other curricular areas, for the reason that, as referred by Sá and Varela (2004), Cachapuz (2006), Martins et al. (2007) and Silva (2009), the scientific process inherent to applied sciences fosters children's communication, increasing their lexical knowledge with new words and terminologies, narrating what they observed, discussing results and making written records.

School trips to nearby institutions constitute an enhancement of the pedagogical action held in the context of the classroom. They have clear objectives and children can participate in inter-related activities already undertaken or planned for later. According to Orion (1993) field trips provide a direct sensorimotor experience, which can facilitate the construction of abstract concepts and can also significantly enhance learning, providing support for the memorization of long-term episodes.

On experiential activities, the emphasis is placed on the children, on how they can generate their own knowledge, learning and meanings. "The child is thus seen as competent and capable, a little researcher who wants to discover the world, who knows he can and should solve problems. The child proves to be able to manage his own learning process with adult support; he is the author of himself with the help of others" (Vasconcelos et al., s/d, p.18).

But we should also bear in mind children's alternative conceptions. These may impact on the whole learning process. Cachapuz (2006) argues that "learning Science isn't easy under the cognitive point of view, because it often contradicts common sense convictions" (p. 28). These concepts are logical and present themselves "with a structural and systematic nature, through which the child seeks to interpret the world, giving meaning to the relations between objects and social and cultural relations that are established with these objects" (Martins et al., 2007, p.30).

It is crucial that the teacher, in his pedagogical practice, identifies children's conceptions and conceptually contrasts them, via concrete and meaningful activities that challenge the children with the real facts, in order to facilitate the process of changing conceptions. Although these processes of (re) building - or not -the knowledge, of recognizing, of evaluating and of reviewing other aspects of understanding as being individual, they are also closely influenced by how teachers structure their teaching practice (Ferreira, Reis, Tracana, Leitão and Carvalho, 2007), and how the classmates affect the learning environment.

In the socio-constructivist perspective, it is of key importance that the construction of knowledge and learning occur through child-teacher and child-child interaction, favouring group work which will foster tutorial and collaborative work. The inclusion and sense of belonging to a learning community group, is a factor that benefits participation, involvement, sharing ideas and learning (Arends, 1995).

Each school has an educational project. In our case - the school where the practices of the master in the training of primary teachers taken place - whose theme was "Air". Given that the properties of air (a curriculum content area of "Environmental Studies") arouse curiosity in children, and, as Sá states (2000), phenomena and facts involving air are difficult to understand for this age group, we consider that the development of group experimental activities, in which there is observing, performing and recording, that could provide significant learning, constitutes a challenge. According to Ausubel (2003) "meaningful learning is not synonymous with learning meaningful material" (p. 1) and according to Silva (2009) "the teacher should guide a process in which children are becoming active observers with the ability to discover, investigate, experiment and learn" (p.23). In this perspective, we explore the following air properties: how it occupies space, exerts pressure, has strength and is compressible.

3. Issues and Objectives

In articulation with the context of this pedagogical-didactic intervention, we adopted as a research problem to understand to what extent the realization of practical activities in a primary school class, with children of different grade levels, 1st and 3rd years, promotes the learning of science and has repercussions in other school

skills. We conducted a survey of previous conceptions and valued these learning dimensions. We have considered the following research questions:
(a) Will there be effective contributions in child learning in classes formed with different educational levels, namely 1st and 3rd year of primary school, using experimental activities in science?
(b) Are there actual contributions of experimental activities in the affective development of children?
(c) In what way is the relationship established between different contexts, classroom and higher education laboratory, in order to promote the learning of science significantly, within the curricular framework, in classes formed with different educational levels, namely 1st and 3rd year of primary school?
Thus, to provide answers to the questions we raised, the following learning objectives were defined:
(a) To build and validate teaching resources, which emphasise experimental activities in science learning as a learning experience promoting the acquisition of knowledge in the primary education curricular areas (Environmental Studies, Mathematics, Mother tongue and Arts).
(b) To demonstrate the relevance of experimental activities in the children's emotional development.
(c) To highlight the contribution of the school visit to an energy and environment laboratory of the School of Technology and Management (EA/ESTG), for the curricular learning of children in the 1st and 3rd year of primary school.

4. Methodology

Considering the research problem and study objectives, we opted for a qualitative research, based on action research (Carr and Kemmis, 1988). Since it was a small-scale intervention, the fundamental purpose was related to the detailed analysis of the effects of this intervention with a view to the possibility of change (Cohen and Manion, 1990; Elliot, 1989).

In order to meet the purpose of our investigation, we followed the planning-observation-reflection cyclic action dynamics, employed by Mactaggart and Kemmis (1988), in order to improve our professional skills and contribute to the understanding and improvement of our educational practice.

This study was carried out in the context of supervised practice in elementary school and involved, in an active and direct way, a group of 12 children, 8 from the 1st year (aged 5 and 7 years) and 4 from the 3rd year (ages vary between 7 and 8 years), and its head teacher from a school in an inland town in Portugal.
The procedures for data collection privileged participant observation, field notes and children's written records (text and drawings).

5. Development of the pedagogical intervention

In a first stage, 3rd year children were asked:
How do you want to learn the properties of air?
They decided it would be by means of research, with the collaboration of parents, and *via* experiments. It was decided that:
(i) This theme would be studied in the classroom, every Friday, for 2 hours.
(ii) 3rd year children would guide 1st year children in the execution of experiments.
(iii) They would make a school visit to a higher education laboratory in the city.
(iv) They would do an activity they named "Being a Teacher." It would be a lesson in which they would replicate the experimental activities to the other 1st year class from the same school.
(v) They would participate in the town spinning-top festival, organized by a group of schools in the city, in the town square, by exhibiting their records of experimental activities.

The involvement of children in the selection of learning strategies is an educational process facilitator, since it fosters a greater interest in the activity which is going to be developed (Breen & Littlejohn, 2000).

Recognizing that proper planning of pedagogical practice is essential for its success, we designed resources and teaching materials to be used in experimental activities with the children:
(a) Child learning itineraries with didactic phases of exploration activity. All the itineraries obeyed the following didactic exploration sequence: a short introductory story whose characters were the little scientists; the problem-question; identification of the materials used in the experiment; record of the previous conceptions about the problem-question; experiment implementation; record of observations; clash with previous conceptions; conclusion. The learning itineraries for the 1st year were adapted, since this group of children does not yet have a complete domain of their mother tongue.
(b) A child's school visit guide, with the essential guidelines for the various experimental activities designed.

In this pedagogical intervention we developed:
(a) In the classroom context, three sequential, articulated and increasingly complex activities: "The rocket balloon", "The submarine" and "Magical breath".
(b) In the EA/ESTG lab, seven activities: "The swing", "Let's blow", "Blowing speed", "Bringing down the house", "Airplane", "Generating power" and "Let's cook". The day before the school visit, we analysed with the

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children, the precautions they should take and the importance of group cohesion and autonomy, with a view to achieving successfully the proposed activities. Pupils showed excitement and enthusiasm for a class that would take place in a different space, a higher education lab in town. They were expectant and very curious about what they would learn, by investigating /experiencing.

We have observed a strong motivation in class. According to Balancho and Coelho (2005):

> motivation is not complete until the child finds reason enough for the work that he performs, when he enjoys its value and realizes that his efforts lead to the creation of the desired ideal. The best way to motivate school work is to present it as an interesting activity or experience (p. 21).

Children were given:

(a) A learning itinerary, for each activity in the classroom, which they would have to follow and fill in as the activity unfolded.

(b) When they were in the laboratory, a school visit guide, which they would have to follow as they passed by the different benches that were organized according to the sequence of activities proposed.

The lesson plans for all experimental activities were arranged with goals that favoured both conceptual understanding (terms and concepts related to content; cross /interdisciplinary knowledge), the development of abilities (Observe, Identify, Describe, Predict; Register, Interpret, Infer, Evaluate) and attitudes (Autonomy, Responsibility; Cooperation) and the development of the affective component (Engagement, Initiative, Curiosity, Creativity).

We have chosen to focus only on two activities, which aroused particular enthusiasm in children: “Magical Breath” and "The Swing", developed, respectively, in the context of the classroom and in the EA / ESTG laboratory.

The learning script for "Magical Breath" depicts its characters on the 1st page, which we adapted from the original, "The Original Rocket" by José Sacramento. This story was explored in the first lesson of this pedagogical intervention. Each character's story represents one child in the class, and its exploration constitutes the motivation for the sequence of activities to develop about "the air". According to Witter (2004), the motivation for learning may be associated with environmental factors such as the internal factors (e.g., the desire, the excitement and the interest) or the object itself, which can be attractive or not for the child.

In each activity these "little scientists" tell a story that:

(a) Contextualizes the activity;

(b) Challenges children to discover: "Our challenge today is to fill a balloon without blowing and figure out how it happens";

(c) Introduces a problem-question: "What happens to the balloon when the bottle is dipped in hot water? And when it is dipped in cold water? “;

(d) Encourages the registration of previous conceptions: first-year children make their prediction by drawing and third-year children describe and justify their predictions.

In order to find the solution to the problem-question, children follow the guide for the experiment, and use it to identify the necessary material, follow the procedures and record their observations conceptions (figure 1).

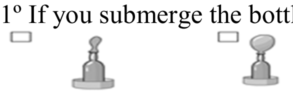
Let's do the experiment to find out how the magical breath works.
To start you need: (identify the necessary material) _________;_________;_________;_________;
Put in order the steps you must follow to do the experiment (procedures). ☐ Immerse the bottle in the bowl with hot water for one minute; ☐ Immerse the bottle in the bowl with cold water; ☐ Place the balloon in the bottle; ☐ Put hot water in the bowl (with your teacher’s help); ☐ Put cold water in the second bowl.
And we found that...
1º If you submerge the bottle in the hot water bowl the balloon ...  2º and when you plunge the bottle under cold water the balloon ...” 

Figure 1. Part of the child's learning itinerary concerning the "Magical Breath" and its implementation.

Regarding the school visit script to the EA / ESTG laboratory, this started with a text, with an image of the 12 little scientists, who challenged them to make discoveries (figure 2).

"The little scientists are going on a study trip in order to investigate a little more about the air. Yeah, they will visit the Climate and Environment lab at the IPG's School of Technology and Management. In the laboratory, the little scientists will observe and perform many experimental activities, which will make them learn new things and they will have lots of fun."

Figure 2. Script introduction about the school to the EA/ESTG.

The activity named "The swing" (Activity number 1) had the following learning route (figure 3).

Let's build a swing similar to the picture.
The two balls that are suspended must be immobile and 2 cm apart.

1. Choose what you think is going to happen.
   What happens if you blow air into the middle of the two balls?
   ☐ The balls meet.
   ☐ The balls move apart.

Let's check...

Try blowing fast and intensely, blowing in between the two hanging balls and relatively close to them.

2. Choose what you check
   ☐ The balls move away, because your breath is very strong.
   ☐ The balls meet because when you blow hard you blow away the air that is in the middle of the two balls, and they come close to fill the air space.

Figure 3. Activity: "The swing".

Upon returning to school, as a complement to the school visit, the children took the exercise found at the end of the script. This was an exercise to structure learning. They also recorded, in an individual text, their overall assessment about this class, outside their usual classroom. Throughout the educational intervention the class teacher was always present as an observer.

6. Results

As regards the problem-question which children had to answer, about the activity "Magical Breath", each group element made different forecasts, recorded in the children's itinerary:
"-I think the balloon inflates when the bottle is dipped in hot water.
- I think that nothing happens to the balloon when the bottle is dipped in hot water."

We found that this activity provided ability building opportunities, including observation, description, registration and also allowed them to infer and evaluate. Considering this activity as a didactic tool for the acquisition of knowledge related to science content:
"-When the bottle is dipped in hot water the balloon inflates because the hot air inside the bottle warms and rises, because it is lighter. And when the bottle is dipped in cold water, the balloon deflates, because the air inside the bottle cools and returns to occupy the space."

We highlight the picture of a first-year child about what she learned from the experience.
"What we did today:" This 7 year-old represents the air with "dots" and represents the balloon filled with air when the bottle is full of "dots".

The activities developed in the laboratory were a clear contribution to the awakening of curiosity by learning through experiments. In their record, children showed enthusiasm and interest in returning to the laboratory:
"- We carried out very interesting experiments about the air.
-We measured the wind speed and did an interesting experiment with rubber balls.
-We had lots of fun with the experiment.
-I would go back there and carry out new experiments."

All the children showed enthusiasm and desire to return to the laboratory. The head teacher also noted and mentioned this aspect, stressing the need to continue to make future trips to this school laboratory, also in view of the interest shown by the children.

The school visit, globally, enabled the children to learn about the properties of the air (figure 4).

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Cross out the wrong choices in order to make true statements.
It is possible / impossible to live without air. Wind is air which is moving / stationary. The air does not occupy / occupies space, has weight, strength and elasticity. The wind, when it is not very strong, it is dangerous / a breeze. The air isn't / is composed of gases. Hot air is heavier / lighter than cold air. Air has no colour, no smell and has no / has taste. The anemometer serves to measure the air temperature / air velocity. Air can generate hydro / wind power. The greenhouse effect is important to keep the air warmer / colder than the temperature of the air in the room. It is necessary / unnecessary to renew the air in enclosed spaces. We should / should not protect the air."

Figure 4. Systematization of knowledge acquired in the school visit.

In the activity "Being a Teacher", with the 1st year class from another room in the same school, we found that children felt happy, excited and proud of their work. There is a different attitude in class, one emerging from a scientific culture, a desire to learn more and discover and explore different materials and learn new content. In the day after this activity, children came to offer their drawings on the experiments to these children-"teachers".

The teacher in charge of the class, in the group, confirmed the occurrence at a satisfactory level of the learning outcomes provided by the activity “Being a teacher” (figure 5), and that only two children displayed difficulties at the levels of attitude and affection.

Abilities						**Attitudes and affective component**					**Knowledge**					
Performs experimental activities with different materials	Explains the experimental activities to colleagues	Outlines the procedures of experimental activities	Indicates the problem-question	Describes the experimental activity	Interprets information	Performs experimental activities independently, responsibly and creatively	Cooperates with colleagues	Curiosity	Creativity	Engagement	Properly uses terms and concepts related to the content of Physical Environment / Natural Sciences	Recognizes the existence of air	Understands that air occupies space	Understands that hot air is lighter	Recognizes the moving air	Indicates the various air properties
X	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	X

Figure 5. Observation graph of the learning outcomes provided by the activity “Being a teacher”.

In the spinning-top festival, organized by the county group of schools, and held in the historic part of city centre, our children participated with the display of their records on experimental activities carried out in the classroom and in the laboratory.

We understand the need to listen to our children about their learning, so we asked them to evaluate the activities. The collection of information about pedagogical practices should enable their evaluation, facilitating the (re) thinking of the strategies used to improve learning (Martín & Moreno, 2007).

We started by talking to the class about all the activities and goals and we checked whether the proposed goals had been achieved. Then, in a double-entry table, children evaluated all the developed activities, using the following caption: *I really liked it*, *I liked it* and *I didn't like it*. All the children answered *I really liked it* for all activities and commented that they liked learning the properties of air through experiments and that they wished to learn new content with the same methodology.

7. Conclusion

Based on direct observation and analysis of child records in the learning itineraries and in the school visit guide, built for the proposed activities, we see that these resources have noticeably contributed to develop/provide apprenticeships, at the level of knowledge and abilities, on the properties of air. We found that children, with these experimental activities, revealed conceptual and procedural understanding of the issues-problem-questions presented. The children observed, analysed, discovered, expressed their conceptions, respected, interacted and cooperated with each other. Thus:

> Experiential learning differs from most things that people learn as children. Rather than start with a set of principle or school rules, in experiential learning, learners begin with concrete experiment or activities and then through the observation of their own behaviour and of others, formulate concepts and principles (Arends, 1995, p.535).

Considering the attitudes and the affective component, it seems that this was a significant time in the children's personal and social education process, combined with active learning and socializing.

The results obtained are promising, representing a shift in the focus, whereby children are seen as having a proactive function rather than a passive/reactive role in the teaching-learning process. We support the idea that science education in the early years of schooling is promoter of scientific literacy. There is, however, a need to further develop this didactic research. As a future goal, we also intend to build and validate teaching resources for other curricular sciences contents in primary education and extend this research to preschool education.

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